Modern quantum optics: from single atoms to many interacting spins, photons, or qubits (Physics 572)

Instructor	Kaden Hazzard	**Phone**	607 220 8211
Office	BRK 306	**E-mail**	kaden.hazzard@gmail.com
Office Hours	Wed 12-3p or by appointment	**Classroom**	HBH 22, 10:50AM - 12:05PM TR

Learning outcomes:

Can mathematically represent states of *open quantum systems*: subsystems of larger quantum systems, or which possess classical uncertainty

Derive evolution equations for a quantum system coupled to a bath, master equations

Write down evolution equations for atoms coupled to light. Switch between "light-centered" and "atom-centered" viewpoints, for example by adiabatic elimination

Predict the behavior when atoms are driven in prototypical ways with light: Rabi pulses, adiabatic rapid passage, dressing energy levels, electromagnetic induced transparency

Describe light propagation through media including nonlinear effects: saturation, harmonic generation

Predict when light beams interfere and the experimental consequences. Design homodyne and heterodyne detection methods sensitive to different quadratures. Explain Mach-Zehnder and Hanbury-Brown-Twiss interferometry, and the Hong-Ou-Mandel effect.

Know how to create and predict properties of quantum light: cavities, squeezing, phase space distributions (Wigner function, etc.)

Explain (at a schematic level) how to experimentally realize the above phenomena

Apply these concepts to analogous systems, such as quantum circuits and optomechanical devices.

Awareness of how these ideas are used in quantum technology: quantum sensing, quantum information, quantum simulation.

Course credit: 3 semester hours

Text:

There will be reading assignments out of Scully and Zubairy and Misha Lukin's lecture notes, which are available online at http://lukin.physics.harvard.edu/wp-uploads/Papers/285b_notes_2005-1.Lily.pdf. However, you will find similar material in most quantum optics books. As such, there is no strictly required text.

Resources for the majority of the course:

Scully & Zubairy, *Quantum Optics*

Misha Lukin's notes (linked above)

Meystre & Sargent, *Elements of Quantum Optics*

Walls & Milburn, *Quantum Optics*

The new book by Gardiner and Zoller, *The Quantum World of Ultra-Cold Atoms and Light Book 1: Foundation of Quantum Optics* looks useful as well, though I haven't yet gone through it.

A more precise list of readings is available on the website.

Supplementary resources:

We will also touch on topics covered in Wiseman & Milburn, *Quantum Measurement and Control*, Nielsen & Chuang, *Quantum Computation and Quantum Information,* and Pethick and Smith, *Bose-Einstein Condensation in Dilute Atomic Gases.*

Homework and evaluation:

Most weeks I will assign a homework, with a total number of approximately ten homeworks. These will be assigned on Thursday, due the following Thursday. Problem sets will be available online. You are encouraged to work together in approaching the problems, but should understand and write up your own solutions. A list of students who you discussed with should be written at the end of the assignment.

Additionally, there will be a "teaser question" due at the start of many classes, assigned during the previous class. These are – frequently open ended and conceptual – questions to guide reading and create discussion for the following class. Full credit is given for thoughtful completion without regard to the correctness of the answer. No more than 5-10 minutes needs to be spent on them.

Grades, to zero'th order, are weighted with HW as 50%, teaser questions as 10%, the midterm as 20% and the final as 20%. Perturbative corrections come from my interactions with you during class and office hours, and can only improve your grade.

The Rice Honor Code applies to all of these assignments.

Disability and accommodations:

Any student with a disability requiring accommodations in this class is encouraged to contact the instructor after class. Additionally, students should contact the Disabled Student Services office in the Ley Student Center.